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Sustainable energy policy for Asia: Mitigating systemic hurdles in a highly dense city[☆]

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ABSTRACT

Greenhouse gas emission (GHG) has been increasingly a sensitive issue that is across border and impacting global public interests. While the use of renewable energy technology is perceived as a means to enable delivery of emission-free solutions, its penetration into the energy market has not been timely and significant enough as projected in prior studies. This article aims to illustrate some of the critical hurdles as the policy makers start formulating environmentally friendly energy consumption means for the public in Asian economies. In particular, through analyzing the characteristics in the case of Hong Kong, the authors unveil the challenges for this highly dense city to reach a landscape of alternative energy resources for its transition into a sustainable economy. Education and engagement with the public about a sustainable future, alignment of stakeholders' economic interests and absorption capacity of emerging technologies are argued as the three main challenges and initiatives in mitigating the underlying systemic hurdles that remain to be overcome. Observing the current responses to the externalities by the policy makers in Hong Kong, this study articulates the critical challenges to mitigate these specific systemic hurdles embedded in the existing infrastructure of a highly dense city. Possible mitigating measures to enable deployment of integrative sustainable energy solutions in dealing with climate change are discussed.

Contents

1. Introduction

As greenhouse gas (GHG) emission is an issue of international importance, countries in Asia have been aware of the need to formulate policies to stimulate economic activities that would

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improve the environment. China, for instance, has attempted to formulate energy policy to optimize the use of renewable energy in order to reduce the emission of carbon dioxide. In particular, the citizens of Hong Kong—a special administrative region of China (HKSAR) positioned as the international financial centre in Asia are progressively aware of the city's deteriorating air quality. The Government of HKSAR has looked into feasibility of integrative solutions with an aim to improve the air quality. Nevertheless, the challenge to mitigate such environmental problem is complicated due to dynamics of externalities, diverse interests of stakeholders and lag times in deploying technology.

Prior studies about climate policy and transition into renewable energy in developed economies have suggested the complexity involved in dealing with GHG emission [1]. These studies have identified the hurdles and constraints that need to be overcome at policy levels in order for a regime to turn into an environmentally sustainable one. Moreover, it is critical to provide adequate incentives to innovate while embracing renewable energy technology as a key part of the solutions to reduce GHG emission. An effective transition would need to deal with complexity involved in multilevel of changes as suggested by Grin [6] and more recent studies that have articulated the emerging challenges in Asia for the climate change issues [2].

In this paper, we explore the concept of multilevel perspectives and design of system innovations that needs to be addressed in Asia's development renewable energy policy. Using the case of Hong Kong, this study identifies the systemic hurdles that remain to be mitigated through policy mechanisms that facilitate technological innovation and deployment of effective measures to reduce the carbon footprint of the energy system. Adoption of technological innovation however could be complicated by the divided economic interests of key stakeholders and the existing infrastructure.

2. Transition in Asia

2.1. International perspectives

Despite the increasing awareness of the need to set specific objectives to improve the air quality, there are specific hurdles and constraints to deal with as experienced in other more advanced economies. These constraints are present at different levels within an economic system and have an impact on the subsequent deployment of renewable energy solutions [3–5].

An analytical framework that captures a multilevel dynamic perspective has been elaborated to explain the challenges in managing the transition into a renewable energy regime [6]. At the first level, it is characterized as a technological niche that is by and large dependent on learning processes in which emerging elements of "social-technological configurations" are unveiled. At the next level, a set of regimes, including the social-cultural, the technological and the ultimate policy regimes, would be developed. Being characterized as "social technical regime", particular rules would be in place with alignment of certain activities enabling this level to remain dynamically stable. Then subsequently at the third level of "landscape developments", there would be evolutionary developments that create windows of opportunity for the innovation with participation of outsiders building on the regime level.

Nevertheless, the gradual adoption of renewable energy has gained significance in the developed economies during the recent years demonstrating the effectiveness of pertinent policy development and formulation into the level of landscape developments. In particular, the use of solar energy and wind power has been growing steadily among the EU countries. Despite the number of emerging solar panel production companies in China, most of their productions have been exported to the EU countries, such as Germany and Spain, mostly because of these countries' pragmatic energy policy to drastically reduce greenhouse gas emission [7]. These developments suggest a more advanced enhancement of technological change and innovation taking place in these developed economies under a revised social technical regime. The U.S. experience in promoting renewable energy and efficiency revealed the importance of implementing policy mechanisms in a comprehensive manner by the government in order to overcome barriers of the existing systems at various levels [8].

2.2. The focus on Asia and China

As GHG is a global issue that requires a global solution, there is growing attention to the projected GHG emissions among the developing and steadily expanding economies in Asia Pacific. As examined by Morita et al. [9] through scenario analysis, the emissions resulting from Asia Pacific would continue to increase at a higher rate than the average of the global and could significantly affect the global environment in the future. Their study advocated possible mitigation measures to reduce the impact under these scenarios, through robust technology and policy measures as well as introduction of renewable energy. Morita et al. [9] also noted the possible measures of knowledge transfer to development countries and technological efficiency improvements.

In a recent study adopting the backcasting approach, it is argued that policy making needs to take into account the range of constraints embedded inside an economic system, including the engagement of key stakeholders, in order to optimize the development of concerning policies for adoption of renewable energy for China [10]. Formulating a backcasting-optimization framework, the author points out that both quantitative and qualitative constraints could affect the country's potential goals in reducing emissions of carbon dioxide through sustainable and renewable energy developments. Some of these constraints in the framework are consolidated into three main areas under Table 1.

Table 1
Key constraints for technology niche.

Education and engagement about sustainable development	Alignment of stakeholders' economic interests	Absorption capacity for technological solutions
Education about sustainable development	Incentives in energy policy for renewable energy generation	Design of customized solutions in a highly populated and condensed city
Knowledge about climate change	Integrative policy to induce support among stakeholders	R&D for product localization
Public engagement about values, preference and beliefs	Commitment to capital investments for renewal of technological infrastructure	Knowledge/technology transfer
Consensus about common goals	Cost effectiveness of solutions	Training and development of relevant human capital for energy efficiency and renewable energy sector developments

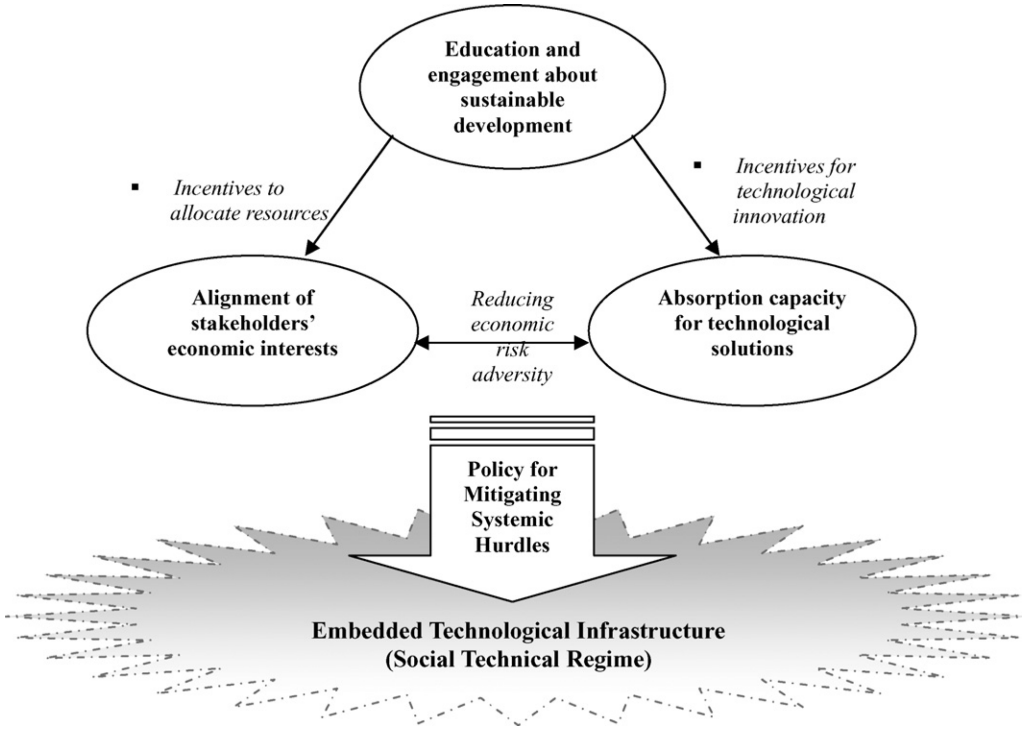

Fig. 1. Inducing integrative policy for mitigating systemic hurdles.

2.3. Embedded technological infrastructure and underlying systemic hurdles

With reference to the multilevel perspectives, the policy development for renewable energy could be complicated by the first two levels, namely the "technological niches" and the "social technical regime" embedded among emerged economies in Asia. The backcasting-optimization model by Ng [10] summarizes the importance of synthesizing inputs from stakeholders, alignment of economic interests and the integration of new technology for timely innovation in local deployment of renewable energy solutions. For countries in Asia, the intangible elements of education and knowledge development for advancement of "technological niche" could be critical to the transformation of the existing "social technical regime" and the subsequent "landscape developments".

As illustrated in Fig. 1, the process towards development of sustainable energy policy would be further influenced by the availability of incentives to allocate appropriate economic resources to renew the existing embedded technological infrastructure as well as to facilitate technological innovation. In terms of technological infrastructure, it should embrace a range of assets, including plant, facilities, equipment, enterprise systems and networks, which facilitate the process of technological innovation as well as delivery of operational activities, ranging from production and manufacturing to logistics management [11]. As such, the existing electricity and energy delivery systems embedded in an economy may not embrace participation of a heterogeneous component. Such phenomenon is consistent with system theory that suggests the criticalness of feedback through "energic importation" so as to provide signal to the system about environmental conditions; otherwise, a system might tend to cope with externalities by "ingesting" or "acquiring control" over them [12].

With respect to absorption capacity, this refers to the ability of a society to "recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities" as conceptualized by Cohen and Levinthal [13]. Deficiency in absorption capacity of a society for sustainable development and renewable energy could be detrimental to alignment of stakeholders' interest as perceived risk might be amplified. In fact, education and public engagement relating to the science and technology for sustainable development becomes the key to the enhancement of absorption capacity.

3. The case of Hong Kong

3.1. Case study

Hong Kong has been a special administrative region (HKSAR) of China since 1997 strategically positioned as the international financial centre in Asia. With its role of the economic gateway to China, HKSAR's proximity to the Pearl River Delta has also given itself the advantage as one of the fastest economic development regions of the world. As the air quality of the city has continued to deteriorate in the recent years, two major sources of air pollutants were found to be combustion from power generation based in HKSAR using fossils and vehicular emissions threatening its newly repositioned role as the international financial centre in Asia, it has been reported that expatriates and investors might be turned away from HKSAR. [14] In the long run, there would be adverse impact on the health of the people residing in this international city. Adopting the case study approach as deliberated by Yin [15], this paper explores how this international city of Asia has attempted to formulate its comprehensive approach in mitigating the hurdles for sustainable development. Being an Asian city of population closed to 7 million within a limited area of 1067 km^2, its road to sustainability can be viewed as highly challenging and its experience would be of relevant reference to other Asian counterparts.

3.2. Embedded technological infrastructure

As technological infrastructure has been defined as system of knowledge and network embedded inside the existing system [11],

it is referred thereafter to the range of current "regimes" connected with key stakeholders. Three crucial systemic hurdles embedded within the technological infrastructure of HKSAR identified in this study include (a) the power generating system, (b) property development system and (c) the road transport system.

The power generating system of HKSAR has been regulated through the Scheme of Control (SOC), a contractual agreement between the power producer and the government for over 40 years. Nowadays, two electric utilities—Hong Kong Electric (HEC) and CLP Power (CLP) dominate for the power supply business in Hong Kong for their respective divided local markets ranging from power generation, transmission and distribution to end-users. As reported by Lam [16], there has been no direct competition between these two private players and the principles in SOC allow adjustments of tariff in order to protect financial returns of these two electric utilities. However, under the current regulatory regime, there is a lack of performance-driven parameters that would provide incentives to be environmentally sustainable. It would not be feasible for new sources of power generation generated externally, such as renewable energy, to be given access to the grids controlled by HEC and CLP unless such facilities were unbundled from the existing infrastructure [16]. In fact, the two players as publicly listed companies in HKSAR continue to rely on imported coal as the main fuel for their power generating activities with the failure attempt by CLP in a few years ago in their plan to adopt more natural gas as the fuel supply (Table 2) [14].

Secondly, the highly condensed built environment of HKSAR is another concern that is interrelated with energy and environmental sustainability. Living in a densely populated city, people of HKSAR inhabit in vertical building structures for living, work and social activities. With respect to energy efficiency, electricity consumed through buildings in HKSAR has been accounted for 89% of total power consumption according to the government [14]. In order to mitigate such customary consumptions, there have been different suggestions to increase energy efficiency buildings through higher efficiency thermal systems, electrical appliances and lightings, enhancement of building envelope thermal characteristics [19]. In relation to improving the sustainability of the living environment, the public has enquired about possible measures to reduce the impact of property development on the environment under the constraint of limited supply of land resources. The existing development control framework for building developments nonetheless does not seem to induce appropriate incentives to innovate for a sustainable environment [20].

Based on a study in 2006, it was unveiled that another main cause to the worsening air pollution in HKSAR was the gas emissions, including NO_x and volatile organic compounds (VOC), from vehicles operating in the current road transport system [14]. As one of the highest densities in terms of road traffic in the world, the city has now over 500,000 licensed vehicles and one-fourth of them use diesel fuel. There are heavy and medium diesel vehicles running the city, including franchised buses, which do not use the best available fuel technologies to minimize their emissions. The problems of vehicular emissions combined with the tall building structures have caused the pollutants trapped resulting in so called "canyon effect".

3.3. Momentum in raising the public's awareness

With the increasing awareness of the deteriorating air quality, the public has expressed their views about the need to drastically improve the sustainability of the environment in HKSAR. The Council for Sustainable Development (CSD) has been established by the Chief Executive of the special administrative region with an objective to promote sustainability in HKSAR. In particular, CSD is assumed to promote public awareness and understanding of the principles of sustainable development as well as to facilitate community participation in the promotion of sustainable development in Hong Kong through various means. Besides relevant public education work, CSD has conducted public engagement exercises attempting to explore views among the stakeholders.

3.4. Proposed temporal solutions

The Environment Protection Department of Hong Kong in 2007 appointed an international engineering consulting firm to review the air quality objectives and development of a long-term air quality for Hong Kong [21]. This study has adopted the Air Quality Guidelines (AQGs) released by the World Health Organization (WHO) in order to revise Hong Kong's air quality objectives. Subsequently in March 2009, the consulting firm through a public forum released its proposed "Phase 1" measures composed of integrated means to tackle the problems that worsen the air quality in Hong Kong. A summary of the proposed measures is provided in Table 3.

While the proposed measures have identified the costs and benefits resulting from each initiative, there is neither detailed indication about the source of funding nor the responsible stakeholders. Furthermore, there is very little mentioning about the elaborate use of renewable energy technologies except for the suggestion of wider use of hybrid/electric vehicles in this phase of proposed measures. With respect to initiatives in the electric power generating sector, there is strong emphasis in the increased

Table 2
Installed capacity of the two electricity utility operators.[a,b]

	CLP	HKE
Installed capacity	CLP operates three power stations in Hong Kong with an installed capacity of 6908 megawatts (MW). It also obtains power from the Guangdong Nuclear Power Station in Shenzhen and the Guangzhou Pumped Storage Power Station at Conghua, both in Mainland China, totaling an installed generating capacity of 8888 MW	Starting from 1990, electricity generation has been entirely carried out at Lamma Power Station. Lamma Power Station is located at a 50-ha site at Po Lo Tsui at Lamma Island. The Lamma Power Station has a total installed capacity of 3736 MW with eight coal-fired units, five gas turbine units, one wind turbine and two combined cycle units
Breakdown of installed power generating facilities by fuel types		
Coal	4108 MW	2500 MW
Natural gas	2500 MW	680 MW
Diesel oil	300 MW	555 MW
Nuclear	1968 MW	0 MW
Renewable	0 MW	1 MW
	8888 MW	3736 MW

[a] Ref. [17].
[b] Ref. [18].

Table 3
Proposed measures for air quality improvement.

Emission capping and control	Transport management/infrastructure development and planning	Energy efficiency measures
Increased ratio of natural gas in electricity generation	Low emission zone for Central, Mongkok and Causeway Bay	Mandatory implementation of building energy codes
Early retirement of aged/heavily polluting vehicles	Car-free zones	Energy efficient electrical appliances for domestic use
Early uptake of latest Euro standard for diesel commercial vehicles of Euro III	Bus route rationalization	LED for street lighting
Wider use of hybrid/electrical vehicles or other environmental friendly vehicles	Expand rail network	Tree planting and roof-top greening
Ultra low sulphur diesel for vessels	Cycling network to major public transportation hubs	District cooling system
Selective catalytic reduction for vessels		
Electrification of aviation ground support equipment		
Emission control for off-road vehicles and equipment		
Strengthening VOC control for sealant adhesives		

ratio of natural gas up to 50% of overall fuel source in light of anticipated increased availability of natural gas supply from the Chinese Mainland. Indication about potential modifications in the existing technological infrastructure to facilitate technological innovation with renewable energy is unnoticeable.

4. Discussion

HKSAR has experienced progression in acknowledging the need to improve its environmental sustainability in the past decade, driven by publics' concerns about air quality and economic sustainability as an international financial centre of Asia. Younger generations are questioning the measures taken to deal with the environment of the special administrative region. Nevertheless, it is an ethical issue for the current generation to devise measures at the policy level to rectify the lingering problems with air pollution and GHG emissions causing the climate change and consequently affecting sustainability for the next generations. As expressed by John Broome, a philosophy professor from Oxford University, "*climate change is a classic example of an externality: it is a case where our activities, the activities that generate greenhouse gases, impose harm on people other than ourselves; externalities generate what economists call a market failure... which is why you can't rely on the market to resolve the problems*" [22].

As reflected in the study by Sovacool [8], HKSAR's experience towards the development of policy for renewable energy and energy efficiency may not be dissimilar to that of the western countries. As part of the cultural and behavior barriers, people in general could remain apathetic about emerging electricity technologies, accustomed towards familiar energy systems, and prioritized for a lifestyle of comfort, freedom and control over energy conservation and renewable power [8]. As such, it would be critical for countering public mechanisms to be implemented in a comprehensive and integrative manner so as to overcome the barriers to development of renewable energy and energy efficiency. In the case of HKSAR, there could be retracting forces caused by the systemic hurdles inside the existing technological infrastructure. Unlike the more advanced economies which have commenced research and development about renewable energy technologies years ago, HKSAR may have relatively less developed absorption capacity of renewable energy and energy efficiency technologies. While some of the core technologies could be transferred from other proven sources, HKSAR may attempt to seek proven technological solutions for a highly dense Asian city if adequate policy measures were taken to induce the necessary sustainable performance among the stakeholders in the *existing social technical regime*.

The incentive to generate a higher return on renewable energy sources than of fossil-fuel is evidenced in HKSAR's recently renewed scheme of control with the two operators, which enables a higher investment return on renewable energy facilities by 1%. The two operators have in fact demonstrated their renewable energy initiatives with further feasibility studies of wind-farm developments in the coastal and outlying island areas of Hong Kong as noted in Table 4. Under these initiatives, the use of wind power would only account for approximately 2.3% of the overall electric power generating capacity in HKSAR.

4.1. Transforming the existing infrastructure

To that end, Hong Kong needs to transform its embedded technological infrastructure into a more open system that facilitates technological innovation for sustainable developments. Through a restructure of the electricity sector, an independently run smart grid could enable integration of independent power producers that generate electricity from complementary renewable energy sources, namely solar and wind. The aim is to embrace an externality for feeding in renewable energy which is allowed a reasonably expected return on capital investment. As explained by Nathwani [23,24] about the imperatives of smart grid development, "*a smart grid can do much more than manage energy demand; it allows renewable power to play a much larger role in the electricity mix, and through rapid integration of power generation from many small distributed sources, we open the door to revolutionizing the way we think about power production and distribution at the local level.*"

4.2. Improving absorption capacity for renewable energy

Absorption capacity needs to be strengthened through domestic research and development activities as well as tertiary

Table 4
Renewable energy initiatives by the two electricity utility operators.

CLP	HKE
Towards the end of 2004, CLP set a target of having 5% of its total equity generating capacity, generated by renewable energy by the year 2010. It then started collaborating with a leading UK wind power developer, wind prospect, to work on the feasibility study for a potential 200 MW offshore wind farm off Sai Kung. It claimed that the planned wind turbine would be expected to supply the electricity needs of about 420 homes in Hong Kong	HKE has worked on the environmental-impact assessment for its proposed wind farm off Lamma Island, which would comprise 35 wind turbines with a generating capacity of 100 MW. The proposal would be ready for public consultation by the end of 2009. HKE's first wind turbine of 800 kW commenced its operations in 2006

education about relevant technologies. Such development of absorption capacity could be initially stimulated by technology transfer through application of proven equipment. The first commissioned wind turbine, which has been installed in Lamma Island—an outlying island of Hong Kong, is a German-made wind turbine. In the meantime, importation of electric cars advocated by the HKSAR would likely come from Japan. Despite the use of proven equipment from overseas, its localization into the domestic existing infrastructure would require specific knowledge about the local operating environment. Continuous education of the public and development of human capital would nurture a progressive development of social acceptance, relevant knowledge and a forward looking culture that facilitates local application of advanced renewable energy and energy efficiency solutions.

4.3. Aligning stakeholders' economic interests

At the policy level, there needs to be an orchestrated effort to align economic interests of the key economic stakeholders who currently control most of the embedded technological infrastructure. An individual smart grid system could create dedicated efforts for a number of stakeholders to participate in transforming the existing infrastructure into a dynamic market platform in order to embrace renewable energy facilities as well as for the future use of electric cars. Distributing ownership of such a smart grip ought to address the balance of interests among the existing ones. Social technical regime would be rebuilt as a consequence.

In particular, performance of these stakeholders needs to be monitored on a regular basis which in turn enables the policy makers to formulate measurable goals and determine achievable targets towards an environmentally sustainable city. With these measurable performance indicators for environmental sustainability, the regulators of relevant policies would be able to monitor regularly and to implement incentive and control mechanisms for reducing GHG emission under an optimization framework [10].

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